COMMUNICATION SYSTEM

[0001] Communication system with network nodes for operating industrial machines, and method for controlling a communication system

[0002] The invention relates to a communication system with network nodes as generically defined by the preamble to claim 1 and to a method for controlling a communication system as generically defined by the preamble to claim 10.

[0003] In the most various areas of technology, communication systems with network nodes of a control and/or drive network are used for operating industrial machines. A communication system with network nodes, in a first embodiment, connects a plurality of network nodes over a closed signal path to form a network. Data and control signals are passed through all the network nodes over the ringlike signal path. One network node is embodied for instance as a control unit. In a master/slave configuration, one control unit is provided that performs a master function and controls the other control units, which perform slave functions. For instance, a control signal is output by the master control unit via an output into the signal path and is received again via an input from the closed signal path.

[0004] To assure reliable signal information, it is for instance known, along with a primary ring as the signal path, to dispose a further signal path as a secondary ring. The secondary ring is embodied parallel to the primary ring and represents a redundant data line. If one of the two signal paths fails, then the other, intact signal path takes on the task of exchanging the data between the control units.

[0005] It is also known, in the event of failure of a data connection of the primary ring or secondary ring, to build up a single closed signal path via the remaining intact connections of the primary and secondary rings. To that end, the network node has switchover units, which perform a corresponding internal switchover. In the process, the primary ring of a network node is connected to the secondary ring of the network node. A generic communication system is described in the documentation entitled "Electronic Drives and Controls", Steuerungssystem-Synax, 04VRS,

Funktionsbeschreibung [Synax Control System, 04VRS, Functional Description], published by Bosch-Rexroth, Chapter 11.09, under the heading "Fehler im Primärring" ["Flaws in the Primary Ring"].

[0006] From German Patent DE 19 708 985 C1, a method and an apparatus for maintaining angularly precise synchronism of individual linked drive mechanisms of a decentralized drive system are known. In the described apparatus, the decentralized drive mechanisms are connected to one another in the form of a communication system. Control data from a guide system are made available to the individual drive mechanisms via a ring line. If the bus system used fails, then for the angularly precise synchronism of each drive mechanism with an adjacent drive mechanism of the decentralized drive system, in each case instead of a predetermined guide set-point value as the location set-point value, an actual machine location value of a drive mechanism located technologically upstream is used, and in each case as the actual location value, instead of the actual machine location value, an actual motor location value is used. Thus each drive mechanism, if the bus system fails, is capable of maintaining angularly precise synchronism with the adjacent drive mechanism, and as a result the drive system can be stopped without destruction.

[0007] The object of the invention is to furnish a communication system that has network nodes of a control and/or drive network and makes increased flexibility of design possible.

[0008] The object of the invention is attained by the communication system having the characteristics of claim 1 and the method for controlling a communication system as defined by the characteristics of claim 10.

[0009] One advantage of the invention is that the communication system has a plurality of networks, which can be configured flexibly. In this way, the network structure can be adapted to malfunctions of the network nodes or of the control units connected to the network nodes. The configuration can furthermore be adapted to various machine conditions as well. Depending on the particular application it may be advantageous to incorporate a network node into a first or a second network. For instance, control units that fail relatively often can be into small networks or

incorporated into networks upon whose failure either a malfunction is rapidly detected or only a slight impairment of the entire communication system results. Thus the communication system as defined by claim 1 offers increased flexibility in the distribution of the various networks, which furthermore have signal paths that are independent of one another. Because of the independence of the signal paths, if one network fails, the capability of the other networks to function is advantageously unimpaired.

[0010] In a simple embodiment of a communication system, two networks can each be connected to one another via a bidirectional signal path, and the bidirectional signal path can be embodied between two network nodes of the different networks. In this way, a simple, economical connection of the two networks can be established. Depending on the embodiment, the bidirectional signal path is represented for instance by two electric lines.

[0011] However, it is also possible that the bidirectional signal path is in the form of two data channels of a time-division multiplex system.

[0012] In an advantageous embodiment, each network node is connected to a control unit. In a simple embodiment, the function of the network node is performed by the control unit itself.

[0013] Depending on the form of application, a network has one control unit with a master function and at least one further control unit with a slave function. By the use of the master function, binding timing codes or binding control commands, for instance, are specified by the master control unit and are used or taken into account by the slave control units. Thus in a simple way, a time axis or signal train that is valid within the network can be specified.

[0014] In a preferred embodiment, the switchover unit of the network node can be switched over via a software controller. The embodiment of the switchover unit in the form of a software controller offers the advantage that the switching position of the switchover unit can be varied in a simple, flexible way. In this way, the configuration of the network can be done without hardware revision work in the communication system.

[0015] A preferred range of application of the communication system of the invention is in a network with control units which, in accordance with a leading axis and following axes dependent on it, perform precisely timed control.

[0016] Preferably, the communication system of the invention is used in printing machines, especially printing machines that have a plurality of printing units. Depending on the embodiment, the control units of one printing unit may be incorporated in a network, or the control units of all the printing units of one printing machine may be incorporated in a network.

[0017] The communication system of the invention furthermore offers the advantage that the function of the control units of the networks can be varied as a function of the distribution of the control units among the various networks. For instance, in a first configuration of the networks, one control unit can perform a master function, and in a second configuration of the networks it can perform a slave function. Correspondingly, the slave function of a control unit can be changed to a master function. Preferably, each network has one control unit with a master function.

[0018] The invention is described in further detail below in conjunction with the drawings. Shown are:

[0019] Fig. 1, a communication system with two networks;

[0020] Fig. 2, a communication system with a modified configuration of the two networks;

[0021] Fig. 3, a communication system for controlling a machine system;

[0022] Fig. 4, a communication system for a printing machine; and

[0023] Fig. 5, part of a communication system for a rotary printing machine.

[0024] Fig. 1 shows a communication system with network nodes 1, 2, 3, 4, 5. The

communication system is divided up into two networks 11, 12. The first network 11 includes the first, second and third network nodes 1, 2, 3. The second network 12 includes the fourth and fifth network nodes 4, 5. Each network node has one switchover unit 8.

[0025] The network nodes 1, 2, 3, 4, 5 are connected to one another via two lines 9. For each signal transmission direction, one line 9 is embodied between each two network nodes 1 through 5. The lines 9 of the first, second and third network nodes 1, 2, 3 form a first ring line 6. The two lines 9 that make an exchange of signals possible in two directions between two network nodes 1, 2 represent a bidirectional signal path 10. The bidirectional signal path 10 has two signal courses, which transmits signals in opposite directions. For each signal course, one line 9 is provided.

[0026] In the embodiment described, the functionality of the first, second and third network nodes 1, 2, 3 is performed by a corresponding first, second and third control unit. The function of a network node is to forward signals over the line and to separate out signals that are intended for the control unit that is connected with network node and forwarded them to the control unit. In a corresponding way, signals of the control unit are fed into the signal path via the network node. For data transmission, a field bus system is used. An association data with control units is made by issuing addresses. To each useful signal, an address is added. The control unit for which the useful signal is intended is thus defined.

[0027] In the exemplary embodiment described, the first control unit of the first network node 1 has a master functionality, which specifies control signals and/or timing signal trains for the second and third network nodes and for their second and third control units. The second and third control units, which perform the functionalities of the second and third network nodes 2, 3, have slave functions. The first control unit acts as the master control unit, and the second and third control units act as a slave unit within the first network 11. The master control unit bindingly specifies control commands and a time-slot pattern for the slave control units.

[0028] The second network 12 has the fourth and fifth network nodes 4, 5. The fourth and fifth network nodes are connected to one another via two lines 9. The two

lines 9 represent a bidirectional signal path 10. The bidirectional signal path 10 has one signal course for each transmission direction. For each signal course, one line 9 is used.

[0029] The lines 9 of the first and second networks 11, 12 each communicate with switchover units 8 of the network nodes 1, 2, 3, 4, 5. A switchover unit 8 of a network node 1, 2, 3, 4, 5 has the functionality that, as a function of the switching position of the switchover unit 8, the switchover unit 8 connects the lines 9 of a network node 1 through 5 with one another, and these lines carry signals in one direction through the network node 1, 2, 3, 4, 5. In Fig. 1, the line 9, which delivers signals from the first network node 1 to the second network node 2 at the input RX, communicates via the switchover unit 8 of the second network node 2 with the line 9 that carries signals from the second network node 2 to the third network node 3 via the output TX. Correspondingly, the switchover unit 8 of the second network node 3 connects the line 9, which delivers signals from the third network node 3 to the second network node 2, to the line 9, which carries signals from the second network node 2 to the first network node 1.

[0030] In a second switching position, the switchover unit 8 breaks the connection of the lines 9 that carry the signals in one direction through the network node 1, 2, 3, 4, 5 and connects the lines 9 of a signal path 10, by way of which lines signals are exchanged between two network nodes, to one another.

[0031] For instance, the switchover unit 8 of the third network node 3 connects the line 9, which carries signals from the second network node 2 to the third network node 3, to the line 9 that carries signals from the third network node 3 to the second network node 2. Simultaneously, the switchover unit 8 of the third network node 3 breaks the connection between the third network node 3 and the two lines 9 that connect the third network node 3 to the fourth network node 4. In this way, the first and second networks 11, 12 are separated from one another with regard to the signal paths 10. The switchover unit 8 of the first network node 1 likewise connects the two lines 9 that extend from the second network node 2 to the first network node 1.

[0032] The second network 12 includes the fourth and fifth network nodes 4, 5.

The switchover units 8 of the network nodes 4, 5 are connected in such a way that the switchover units 8 establish a connection of the lines 9 that are located between the fourth and fifth network nodes 4, 5. Simultaneously, by means of the corresponding switching position of the switchover units 8 of the fourth and fifth network nodes 4, 5, the fourth and fifth network nodes 5 are disconnected from the other lines 9 that are embodied between the fourth and fifth network nodes 5 and further network nodes 3.

[0033] The function of the switchover unit 8 is performed, for instance by a control unit, at least in part or entirely by means of a software program. In this way, by simple execution of a software command, the switchover position of the switchover unit 8 can be changed. Commands of this kind can be issued for instance by the master control unit of a network.

[0034] Depending on the application, preferably at least the master control unit is connected to a data bus, by way of which configuration commands from outside for configuring the networks 11, 12 are delivered. Since the switching position of the switchover unit 8 is variably adjustable, the configuration of the communication system can be adjusted flexibly. This offers the advantage that defects in one line 9, for instance, of a network 11, 12 are excluded. For instance, one of the lines 9, which is embodied between the third and fourth network nodes 3, 4, could be defective. This defect has an influence on the capability of the first and second networks 11, 12 to function, since the first and second networks 11, 12 do not communicate with one another over the two lines 9 that are embodied between the third and fourth network nodes 3, 4. The first and second networks 11, 12 each have their own ringlike, closed signal course. In the second network 12, the control unit of the fourth network node 4 forms the master control unit, and the control unit of the fifth network node 5 forms the slave control unit.

[0035] A further advantage of the flexible embodiment of the differing size of the networks 11, 12 is that the network nodes 1 through 5 can be connected to one another in a different distribution to make various networks.

[0036] In a simple embodiment, all five network nodes 1, 2, 3, 4, 5 could form a single network. All that is required for this is to switch over the switchover unit 8 of the

third and fourth network nodes 3, 4 accordingly. The number of networks and network nodes is not limited to the numbers in the exemplary embodiment but instead can be selected to suit the particular application.

[0037] When the first and second networks 11, 12 are connected to make one common network, the control unit of the first network node 1 or the control unit of the fourth network node 4 takes on the master function, and the other control unit is switched to a slave function. Depending on the particular application, it may also be advantageous not to provide any master and slave control units but instead to use control units with equality of access.

[0038] Fig. 2 shows a further configuration of a communication system, in which the first network 11 includes the first and second network nodes 1, 2, and the second network 12 includes the third, fourth and fifth network nodes 3, 4, 5. The novel configuration based on Fig. 1 is achieved by means of a suitable switchover of the switchover units 8 of the second, third and fourth network nodes 2, 3, 4. Preferably, the switchover is performed by the software by means of a suitable modification.

[0039] An application of the communication system of the invention is advantageous in machine assemblies in which subunits of an overall system each have a plurality of control units, which must be synchronized chronologically synchronously with a leading axis within the subunit. A master axis is a time axis according to which the functions of the control units of the subunit are synchronized. The control units of a subunit can in turn have their own, dependent following axes, or in other words dependent time axes.

[0040] Fig. 3 shows an application of the communication system of the invention in which a first, second and third network node 1, 2, 3 are connected to one another in the form of a first network 11 via a first ring line 6. Each network node 1, 2, 3 is connected in turn to a further ring line 14. Electrically controllable drive mechanisms 13 are connected to the further ring lines 14.

[0041] In the embodiment shown in Fig. 3, the control unit of the first network node 1 takes on the master functionality, which specifies a leading axis for the second and

third network nodes 2, 3. The first, second and third network nodes are realized by a first, second and third control unit, respectively.

[0042] The control unit of the first network node 1 takes on the control of the drive mechanisms 13 that are provided for controlling a printing unit 15 of a printing machine. The control unit of the second network node 2 controls the drive mechanisms 13, connected to the second network node 2, that are associated with a painting unit 16. The control unit of the third network node 3 controls the drive mechanisms 13 that are associated with a stamping unit 17.

[0043] The flexible configuration of the communication system of the invention offers the advantage that depending on the makeup of a processing complex and its subsidiary units, networks of different sizes can be formed. For instance, functions that are of lesser importance for the mode of operation of the processing complex may be controlled in a dedicated network. Functions that are especially critical for a correct mode of operation of the processing complex are likewise handled in a dedicated network. There is furthermore the possibility, for instance in the embodiment of Fig. 3, if the stamping unit 17 fails, to interrupt the signal path 10 between the second and third network nodes, yet printing and painting of a printed item is still possible. Hence failure of the stamping unit 17 does not cause a complete failure of the processing complex of the communication system. A failure of the stamping 17 is recognized for instance by the master control unit of the first network node 1, which performs a corresponding monitoring of the slave control units of the second and third network nodes 2, 3.

[0044] The first network 11 in Fig. 3 is connected to a second network 12, which is not shown, in a manner corresponding to Fig. 1.

[0045] Fig. 4 shows a further application of the communication system of the invention in a printing machine 18. The printing machine 18 has a first and a second printing unit 19, 20. The first printing unit 19 includes eight further printing mechanisms 21, which each have three drive mechanisms 13. The drive mechanisms 13 of the first printing unit 19 are connected to the first network node 1 via a further ring line 14. The second printing unit 20 has five further printing mechanisms 21, which each have three drive mechanisms 13. The drive mechanisms 13 of the second printing unit 20 are

connected to the second network node 2, via a further ring line 14. The first and second network nodes 1, 2 are connected to one another over a bidirectional signal path 10 having two lines 9, as in the embodiment of Fig. 2. The arrangement of Fig. 4 represents a second network 12 corresponding to Fig. 1.

[0046] Based on the communication system of the invention, it is possible to use the single communication system to construct the arrangement of Fig. 3 and the arrangement of Fig. 4. In that case the communication system is subdivided into a first network 11 and a second network 12. In this exemplary embodiment, the first network 11 has the network nodes of Fig. 3, and the second network 12 has the network nodes of Fig.4. The networks of Figs. 3 and 4 can be connected to one another via lines 9 as in the embodiment of Fig. 1, but the signal paths of the first and second networks 11, 12 are operated separately from one another.

[0047] The first and second networks 11, 12 each have one master control unit. If the master control unit of the first or of the second network 11, 12 fails, for instance, and the other control units of the network 11, 12 are incapable of taking on the master function, then an interconnection of the first and second networks 11, 12 may be effected. The master control unit that is still functioning then takes on the master function for the first and second networks 11, 12. Thus in this application as well, the embodiment of a communication system with a plurality of networks which can be configured flexibly has substantial advantages.

[0048] Fig. 5 shows a different embodiment of the communication system of the invention. In Fig. 5, part of a rotary printing machine with two folding machines is shown schematically. Fig. 5 shows part of a first ring line 6, which is connected to five network nodes 1, 2, 3, 4, 5. The first ring line 6 has two parallel lines 9. In this exemplary embodiment, a network node 1 through 5 has an interface 22 and a control unit 23. The interface 22 serves the purpose of data exchange between the ring line 6, which has two lines 9, and the control unit 23. The control unit 23 serves to control drive mechanisms 13. The control unit 23 is connected to the interface 22 via a data connection. In the exemplary embodiment shown, the interface 22 simultaneously takes on the function of the switchover unit 8. The interface 22 is controlled by the control unit 23. The functionality of the switchover unit 8 is preferably implemented via software

programs. The control unit 23 is connected to drive mechanisms 13 of a first printing tower 24. The control unit 23 of the second network node 2 is connected to drive mechanisms 13 of a folding machine. The control unit 23 of the third network node 3 is connected to drive mechanisms 13 of a second printing tower 26.

[0049] The control unit 23 of the fourth network node 4 is connected to drive mechanisms 13 of a third printing tower 27. The control unit 23 of the fifth network node 5 is connected to drive mechanisms 13 of a second folding machine 28. In the exemplary embodiment selected, the control unit 23 of the second network node 2 takes on the master function for the specification of a leading axis A. The first, second, fourth and fifth network nodes 1, 2, 4, 5 have control units 23 that execute slave functions. In the process, the first, second, third and fourth network nodes 1, 2, 3, 4 follow the leading axis A that is specified by the second network node 2. The fifth network node 5 follows a second leading axis B, which however is likewise specified by the control unit 23 of the second network node 2. As in the embodiment of Fig. 1, the network nodes are connected to one another in the form of a first network 11 via the first ring line 6.

[0050] The lines 9 are preferably embodied as optical waveguides. The data transmission via the optical waveguides is effected in a corresponding way via light signals, which are converted by the interfaces 22 into corresponding electrical signals and are forwarded to the control units 23. The embodiment of the data transmission channel is effected in the form of a field bus, such as the CAN bus.

[0051] A further advantage of the communication system of the invention is that existing double-ring topologies can be reconfigured into the novel inventive communication system by suitable switchover of the Rx/Tx inputs/outputs of a network node. Thus even already existing double-ring topologies can be converted into the novel communication system in a simple way.

[0052] The further ring lines 14 for instance represent a Synax control group produced by Indramat. The drive mechanisms 13 preferably have an electronic gear functionality, which enables shaftless synchronization of the drive mechanisms 13. Each control unit of a network node preferably calculates its own leading axis, which is

defined as a function of the leading axis of the master control unit, and which is followed by the drive mechanisms 13 that are triggered by the control unit. The use of a master control unit offers the advantage that the master control unit can be embodied in an especially fail-safe way and is for instance securely supplied with voltage. A failure of the master functionality is thus avoided. Hence a shutoff of the communication system and hence of the triggered machine is assured without damaging the machine, even if there is a defect in one of the further control units. The first and second ring lines 6, 7 preferably represent a closed optical waveguide ring.

[0053] Because of the flexible distribution of the networks, a control unit that is defective or must be switched off can for instance be removed from the other networks. Thus the other networks continue to be functional even though one control unit has been switched off. Hence shutting off one control unit does not impair the capability of the other control units to function.

List of Reference Numerals

1	First network node
2	Second network node
3	Third network node
4	Fourth network node
5	Fifth network node
6	First ring line
7	Second ring line
8	Switchover unit
9	Line
10	Signal path
11	First network
12	Second network
13	Drive mechanism
14	Further ring line
15	Printing mechanism
16	Painting unit
17	Stamping unit
18	Printing machine
19	First printing unit
20	Second printing unit
21	Further printing mechanism
22	Interface
23	Control unit
24	First printing tower
25	Folding machine
26	Second printing tower
27	Third printing tower
28	Second folding machine